Cognitive Psychology 99 (2017) 1–16

Contents lists available at ScienceDirect

Cognitive Psychology

journal homepage: www.elsevier.com/locate/cogpsych

Enabling spontaneous analogy through heuristic change

Thomas C. Ormerod[a,*], James N. MacGregor[b]

[a] University of Sussex, UK
[b] University of Victoria, BC, Canada

ARTICLE INFO

Keywords:
Analogy
Transfer
Insight
Problem-solving
Heuristics

ABSTRACT

Despite analogy playing a central role in theories of problem solving, learning and education, demonstrations of spontaneous analogical transfer are rare. Here, we present a theory of heuristic change for spontaneous analogical transfer, tested in four experiments that manipulated the experience of failure to solve a source problem prior to attempting a target problem. In Experiment 1, participants solved more source problems that contained an additional financial constraint designed to signal the inappropriateness of moves that maximized progress towards the goal. This constraint also led to higher rates of spontaneous analogical transfer to a superficially similar problem. Experiments 2 and 3 showed that the effects of this constraint extend to superficially and structurally different analogs. Experiment 4 generalized the finding to a non-analogous target problem that also benefitted from inhibiting maximizing moves. The results indicate that spontaneous transfer can arise through experience during the solution of a source problem that alters the heuristic chosen for solving both analogical and non-analogical target problems.

1. Introduction

Two influential papers on transfer in creative problem solving opened from apparently diametrically opposed positions. One, a seminal article on analogical transfer (Gick & Holyoak, 1980), began by asking "Where do new ideas come from? What psychological mechanisms underlie creative insight?" (p. 306) and went on to suggest transfer by analogy as the mechanism. The second paper argued that "…it is not transfer we want to achieve in the solution of important problems but freedom from transfer. The creative solution to an important problem may depend on freeing the problem solver from interference from old solutions…if we want to build creative problem solvers, should we teach people to transfer or teach them to avoid transfer?" (Detterman, 1993, p. 2).

The transfer literature commonly focuses on the application of previously acquired skills and knowledge, and this active form of transfer is consistent with the Gick and Holyoak perspective. However, transfer may appear in another form, where what is transferred to a new situation is not the active application of a learned response but the capacity to inhibit a response or to suppress a quasi-automatic tendency. This latter perspective appears to be consistent with Detterman's position, although in our interpretation it would not represent the avoiding of transfer but the transfer of avoiding previously dominant responses, or learning what not to do.

Insight is one area where learning what not to do may be particularly valuable. Insight is generally considered to involve problems in which an initial faulty or misleading representation precludes solving the problem until restructuring or representational change occurs. For example, Remote Associate Tasks (e.g., Bowden & Jung-Beeman, 2003) and Rebus problems (e.g., MacGregor & Cunningham, 2008) often involve insight solutions, and solution may be inhibited when the problems are accompanied by words or phrases that prime a faulty representation (Smith, 1995; Smith & Blankenship, 1989). In such cases, the misleading

* Corresponding author at: School of Psychology, University of Sussex, Falmer BN1 9QH, UK.
E-mail address: t.ormerod@sussex.ac.uk (T.C. Ormerod).

http://dx.doi.org/10.1016/j.cogpsych.2017.09.001
Accepted 19 September 2017
0010-0285/

representation is provided externally. In others, such as the nine-dot problem (e.g., Weisberg & Alba, 1981; MacGregor, Ormerod & Chronicle, 2001) and the six-coin problem (Ormerod, MacGregor, & Chronicle, 2002), an initial misdirection may be caused by spontaneous cognitive tendencies that pre-exist within the problem solver.

1.1. Criterion of Satisfactory Progress Theory (CSPT)

Previously we proposed a theory of insight to explain why initial misrepresentations occur and how restructuring may be initiated via heuristic change (MacGregor et al., 2001; Ormerod, MacGregor, Chronicle, Dewald, & Chu, 2013; Ormerod et al., 2002). The theory proposed two heuristics that guide the selection of moves in problem solving, *move maximization* and *search minimization*, and a mechanism for evaluating candidate moves, *progress monitoring*. Move maximization is a tendency to select moves that maximize progress towards the perceived goal, while search minimization is a tendency to limit the problem space in order to reduce search for possibilities. Progress monitoring evaluates moves against a "criterion of satisfactory progress" derived from the problem description. A candidate maximizing move that is satisfactory with respect to the criterion will be executed.

To illustrate move maximization, consider the nine-dot problem, which consists of nine dots organized in a 3 × 3 array. Commonly, people attempt to draw through as many dots as possible with each line, such as using the first three lines to draw around three sides of the nine-dot figure. An attempt of this type meets the criterion of progress–each line cancels a minimum of the number of remaining dots divided by the number of remaining lines – until the final line is reached and solution is seen to be impossible. However, up to this point of failure, the maximizing heuristic is so successful in meeting the criterion that subsequent attempts often show a similar response pattern, and the initial problem representation persists until a state of impasse is reached (MacGregor et al., 2001).

While the move maximization heuristic helps to explain why the nine-dot problem is so difficult, people do occasionally solve it (Weisberg & Alba, 1981; MacGregor et al., 2001). CSPT explains these occasional successes through *search minimization*, a second heuristic that operates to create and change the mental representation of a problem (Ormerod et al., 2013). Under search minimization, individuals limit the initial representation and subsequent expansion of the problem space to the minimum necessary to permit a search for moves that might meet the criterion. With the nine-dot problem, search minimization constrains the initial problem space to the dot array, which as described above allows for moves that meet the criterion but prevents a solution. Relaxing the search minimization heuristic allows a modification of the problem space, which for the nine-dot problem may include the space around the dot array, as well as other options that may result in illegal moves.

In applying CSPT to the nine-dot problem we further considered the effects of different levels of *mental lookahead* (MacGregor et al., 2001). A lookahead of one comprised the sampling and evaluating of one line, a lookahead of two, of two lines, and so on. However, in CPST, move selection and move evaluation involve different processes and it is theoretically possible for move selection to occur without evaluation. This happens when the problem solver employs insufficient cognitive resources to both mentally sample a move and then evaluate it. In the absence of any lookahead at all ("zero" lookahead), a maximizing move is considered to be selected automatically without being evaluated against the criterion of progress (Ormerod et al., 2013). We found it necessary to make this distinction between sampling and evaluating moves when extending CSPT to the *n*-ball problem, described below, which forms the focus of empirical work reported here.

1.2. The *n*-ball problem

The most recent tests of CSPT used a variety of *n*-ball problems, where *n* can be between 7 and 9 balls depending on the variant used (Ormerod et al., 2013). The *n*-ball problem may be stated as follow: There are *n* apparently identical balls where one is imperceptibly heavier than the others. Using a balance-scale and limited to two weighs only, how can the heavier ball be identified?

For the 7-ball version, a solution is to weigh three balls against three (3v3). If the scale balances then the heavy ball is the one not weighed. If the scale is unbalanced then use the second available weigh to compare two of the three balls from the heavy side. If this weigh is balanced, then the heavy ball is the third ball. If it is unbalanced, then it is the ball on the heavy side of the scale. The solution to the 8- and 9-balls problems is almost identical: First, weigh 3v3. If the scale is unbalanced then use the second available weigh to compare two of the balls from the heavy side. If the scale is balanced, then use the second available weigh to compare two of the balls not previously weighed. If this second weigh is balanced, then the heavy ball is the third ball. If it is unbalanced, then it is the ball on the heavy side of the scale.

In the *n*-ball problem we defined a maximizing weigh as the one that maximized the number of balls in each pan of the balance-scale. We assumed that possible weighs are considered in order of decreasing maximization, starting with the maximizing weigh. For the 7-ball version, the first weigh to be considered (and usually eliminated) is therefore 4v3. Because all but one of *n* balls has to be eliminated after two weighs, we defined the criterion of satisfactory progress as $(n - 1)/2$ balls eliminated after each weigh, on average. We considered a unit of lookahead to encompass the mental sampling and evaluation of one weighing, considering both a balanced and unbalanced outcome of the weigh. If a sampled move discovered under each level of lookahead meets the criterion, then it is selected and if not then the next weigh in order of decreasing maximization is selected (without evaluation). For example, with a lookahead of one, a weigh of 4v3 is initially sampled and discarded, because mental evaluation shows that it results in an unbalanced outcome that eliminates no balls. It fails to meet the criterion of eliminating at least 3 balls, lookahead is exhausted, and the next weigh in order, 3v3, is selected without evaluation.

The 8-ball and 9-ball versions of the problem are solved in a similar way to the 7-ball version. However, in both cases a 3v3 weigh is not the maximizing move and a 4v4 will tend to be preferred to a 3v3 first weigh for problem solvers operating at lower levels of